A Professional Development Model for K-4 Earth System Science Teachers

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Purpose of this Study

The Earth System Science Education Alliance (ESSEA) is an online professional development program for K-12 teachers supported by NASA's Earth Science Enterprise (ESE). The ESSEA mission is to: 1) support universities, colleges and science education organizations delivering K-12 online graduate courses; 2) strengthen educators' understanding of Earth System Science; 3) demonstrate the ability to deliver exceptional professional development to a national audience; and 4) create a solid infrastructure to sustain the program.

ESSEA Online Courses are collaborative, inquiry-based electronic environments in which teachers from across the United States: 1) collaborate in teams of 4-6 participants; 2) reflect in online journals; 3) develop Earth System Science knowledge; and 4) experience e and apply inquiry methods. The courses engage teachers in revealing their knowledge, understanding, and hypotheses about interactions among the Earth's spheres, deciding what they need to know, planning to develop knowledge collaboratively, coming up with a problem statement, gathering, organizing and interpreting information, and presenting results. In a 16-week graduate course, participants study the atmosphere (air), biosphere (living things), lithosphere (land) and the hydrosphere (water) and the sphere's interactions under different conditions.

The purpose of this study was to explore the nature of the effect of the online K-4 course design on teacher knowledge of Earth systems science and their understanding of inquiry methodology. Specifically the focus was to develop a theory of how immersion in the methodology would affect teachers' beliefs and practice.

Design and Theoretical Framework

The K-4 course was designed to engage teachers in inquiry for the dual purposes of having them learn Earth systems science and as a model for how to engage their students with Earth systems science.

The 16-week course begins with a three-week introduction to inquiry and Earth systems science analysis through teamwork. This startup time is followed by four 3-week cycles. Each week contains individual and group activities, action and reflection, independent and collaborative tasks. These juxtapositions create the need to consolidate understanding and present it to others or reflect on it in a private journal or discussion space. Each week's activities are designed to use the strengths of the K-4 teachers, while extending their skill and knowledge to new areas. K-4 students need short focused activities to engage their attention (AAAS, 1993). These activities need to reveal student thinking so as to give the teacher the opportunity to coach students and plan additional activities to evolve their understanding.

Design - Week 1

The goal of the first week of each cycle is to give teachers a new perspective on their students as they are engaged in activities. What are their theories? What satisfies them, or qualifies as true? By shifting the teachers' focus to understanding student thinking, she can be the "thinking coach" while the students inquire into content. Here is an example of an activity teachers conduct: teachers provide sand and dry, powdered clay (and silt, if possible) as examples of small rocks. Students explore and compare the wet and dry properties of each and compare the samples to larger rocks. They invent their own recipes for mixing the materials in many different proportions and comparing the resulting mixtures.

A growing body of science educators state that students should learn science as a process and should engage in meaningful, relevant tasks that allow them to interpret their world in scientific terms (Tobin, Tippins, Gallard, 1994). The NRC, 1996 reform effort requires a substantive change in how science is taught. Much current professional development emphasizes traditional lectures with the usual focus on technical training about teaching. Instead, suggests the NSES, "…professional development must include experiences that engage prospective and practicing teachers in active learning that builds their knowledge, understanding, and ability" (p. 56). Teachers must experience the vision of science and the way it is learned in accordance with the standards if teachers expect to use them with students. As stated in the NSES, "Simply put, preservice programs and professional development activities for practicing teachers must model good science teaching as described in the teaching standards…" (p. 56).

Design - Week 2
The goal of the second week of each cycle is to have teachers experience inquiry with coaching. Guided by their own questions as well as some essential questions, they find out what they know, what they believe, and what their own theories are. For example: How do rocks change? Where does soil come from? How does soil help plants grow? What happens to plants when they die? How do Earthworms affect the soil? Students should discuss how the interaction of air, water, sun and living organisms affect rocks.

The standards call for students to be actively engaged in scientific inquiry — alone and in groups — in developing understanding about the natural world. Students are to conduct inquiry into authentic questions generated from experiences. This requires students to pose questions about scientific phenomena, develop plans for investigation, gather and analyze, and interpret data, and present findings or recommendations. The standards state that "changes required in the educational system to support quality science teaching are major ones" p. 56."

Design - Week 3
The third week of each cycle has teachers apply what they have learned to their classrooms through designing lessons that incorporate the content and methodology they have learned in the first two weeks. They reflect, create, give each other feedback and present their lessons for evaluation with a rubric that was applied in the first week of the cycle.

To prepare teachers to function in an inquiry environment, the NSES standards state that college faculty must develop courses based on investigations. Engaging in collaborative work allows teaches to experience inquiry methods, along with its rewards and challenges. Loucks-Horsley, Hewson, Love and Snider (1998) in their book, Designing Professional Development for Teachers of Science and Mathematics, state that principles that guide reform for students' learning should provide guidance for teacher professional development. Reminding us that teachers teach as they are taught, so engaging them in "active learning, focusing on fewer ideas more deeply, and learning collaboratively are all principles that must characterize learning opportunities for adults" (p. xix). Their model includes individual teacher reflection, a focus on learning or improvement, mechanisms for feedback and sharing, and opportunities for interaction. They also recommend a climate of trust and collegiality, a long-term commitment to interaction, and skill building in coaching and mentoring. Week 3 is designed to extend the collegiality from learning together to applying what they have learned to their own work.

Design of the Study
During the 1999 -2000 school year teachers completed the K-4 course. A sample of 12 teachers was studied to examine the effect of the course knowledge of Earth System Science and inquiry methodology.

A combination of qualitative and quantitative research methods was used to explore the degree and nature of the effect of the course. This combination is recommended by several researchers to provide a full and credible picture of the phenomena (Strauss and Corbin, 1990; Patton, 1990; Russek and Weinberg, 1993) Gain scores were calculated on a pre/post course survey to triangulate with interview and observation data. Teachers were observed (non participant method, videotaped) to collect data about implementation of inquiry methodology. Goetz and LeCompte (1984) guidelines informed the analysis of the videotaped lessons.

Teachers were interviewed (semi-structured) to explore the effect of the course on their beliefs and practice. Open coding was conducted on the observations and interviews to identify themes from the raw data, followed by axial coding to develop a model (Strauss and Corbin, 1990). The purpose of the coding was to describe, better understand, provide descriptive details of the teachers' beliefs and practice in relationship to the course, and develop a conceptual model.

The research team performed document analysis on the lessons teachers created in the third week of each of four cycles using the rubric for effective lessons. Multiple researchers reviewed transcripts and documents.

Results and Conclusions

K-4 teachers Earth System Science content knowledge increased as indicated by their increased accuracy and focus in lesson, their self-report on the surveys, their interview responses, and their accuracy in observed lessons. In the interviews, teachers attributed changes in their content knowledge to the course, particularly a greater understanding of Earth System Science - "how everything fits together" as one teacher put it. They reported changing how they develop curriculum - to make it "more connected around the relationships of the spheres, rather than just teaching them one at a time." They think about teaching topics throughout the year - revisiting the essential questions throughout the year.

Teachers also report changing their methodology to engage students in more inquiry- based activities (survey and interviews). Observation analyses indicate structuring of activities for student investigation, coaching for inquiry, teacher acceptance of student ideas, and a high percentage of student talk. Teachers report being more interested in student questions, structuring lessons around what students ask and developing more activities to support their inquiry. They report this as a positive change - "the students are learning more" and "the students really like to learn this way."

Interviews and self report indicate more change than analyses of the observations and lessons revealed. Teachers seemed to have adopted the concepts and were learning how to implement them consistently. For example, a teacher who talked about the importance of student talk, still responded to each student question when she was collecting them from the whole group, making the teacher talk predominant.

A model of teacher change was developed to show the relationship of immersion in the methodology and content to classroom practice.

Educational Importance of the Study

This study provides in depth analyses of teachers engaged in an intensive 16 week course designed to affect what they know about Earth systems science and how they teach it in their classrooms.. The combination of their own scholarly work, experiencing inquiry and applying it in their classrooms affected each of them and their students.

Eisner (1991) suggest three features to consider when judging qualitative research: coherence; consensus; and instrumental utility. We asked ourselves about these things. Does the story make sense to the teachers involved, the course developers and the reviewers? Yes, the story is internally consistent and credible. The teachers were able to integrate their experience and knowledge through the repetition of the four cycles in ways that made sense to them and to the team of developers and researchers. Do the data help us to understand our respective experiences with more clarity and insight? Yes, the data collection provided an additional level of reflection and categorization that helped the teachers to consolidate their understanding, the developers to understand the nuances of the course design, the course facilitators to understand how their modeling is transferred to the teachers' classroom, and the researchers to understand the stages of implementation by the teachers.

This study is important for K-4 educators because it shows how teachers can extend their activity orientation to concept development, expand their classroom management to be guided by student questions, and support their students in inquiring into the essential questions in Earth System Science.

These results are also important for teacher educators because they show that challenging content closely tied to teachers' work with students can result in knowledge changes in science content. Key to the success of this course may be that course content was immediately and directly applicable to classroom practice. For example, the essential questions were written at a K-4 student level so they can be used in the classroom.

These results are important for science educators, and science teacher educators because they indicate that both the content and the methodology are essential for teachers to make the shift to inquiry-based learning and an integrated approach such as Earth System Science. When the content and the methodology are used to teach the teachers, they experience as well as think about the approach. They experience inquiry from the student perspective.

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